AN EXPERIMENTAL INQUIRY

INTO THE

NUTRITION OF ANIMAL TISSUES

BY

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NUTRITION OF ANIMAL TISSUES.

ON THE MOLECULAR CONSTITUTION OF ANIMAL TISSUES.

The object of the present memoir is to give a description and explanatory statements of the investigation I have undertaken into the phenomena of the nutrition of animal tissues, these inquiries relating more particularly to the nutrition of muscles and lungs in health and in cases of phthisis: and I must begin by acknowledging the valuable assistance of Messrs. H. Bassett, F. A. Manning, and M. J. Salter in the analytical portion of the inquiry; I am much indebted to these gentlemen for the care they have bestowed on the work.

The subject is treated by methods of investigation which may be considered new; it is therefore necessary that I should enter into their details, so as to make the mode of reasoning, the analytical process adopted, and the results obtained equally and thoroughly clear to the reader. By this means, only, can I hope to forestall objections and establish the correctness of my work.

I must beg leave to begin with a few introductory remarks relating to liquid diffusion, a subject which has been so admirably treated by Graham.

If we suppose a solution of common salt, on which a flat piece of cork is floated, and if a stream of water be poured carefully upon the cork, the water will not mix immediately with the solution of salt, but form an upper layer in the receiver, while the solution will occupy the inferior layer. Supposing no cause whatever to agitate

the fluids, that they be neither shaken nor subjected to any current of air, they will, however, undergo a tolerably rapid process of mixing, the solution of salt moving into the water, or in other words, distributing itself throughout the water. This phenomenon is called *Liquid diffusion.*

The rate at which diffusion takes place varies according to the substance in the solution; hence it is said that different solutions have different rates of diffusibility. Chloride of sodium may be regarded as yielding aqueous solutions possessed of this property in a very high degree; while white of egg or blood allow of the distribution of their albumen through water at a very slow rate indeed.

Now, supposing that a jelly be prepared, by dissolving isinglass in a weak solution of chloride of sodium (in a strong solution the jelly may not set). If distilled water be poured over this jelly, the salt will by degrees find its way out of the jelly into the water, and will continue doing so until it be distributed equally throughout the jelly and the water. Should the water and the jelly occupy the same bulk, we shall find, after a certain number of hours, the same amount of chloride of sodium in the jelly and the water. Should the volume of the water be twice that of the jelly, a certain bulk of the water, after complete diffusion, will only contain half the amount of salt present in an equal bulk of the jelly, and so on. On the other hand, if a solution of common salt in water be poured over a jelly of gelatine, after a time the salt will be found distributed throughout the water and jelly proportionally to their respective volumes. Should a jelly be prepared consisting of a mixture of a solution of isinglass and white of egg, it will exhibit, with reference to the albumen it contains, diffusible properties entirely at variance with those observed in the case of the mixture of jelly and salt. When water is poured over this albuminous jelly, the albumen will not diffuse out, or its diffusion will be extremely slow; hence a jelly containing albumen has such a thorough hold upon it that this substance can no longer be extracted from the jelly; no amount of trituration or

pounding or washing will separate the albumen; this simple want of diffusibility caused the albumen to become firmly united with, or fixed by, the isinglass jelly.

Graham has observed that, as a rule, substances possessed of the property of crystallizing (such as common salt or sugar) yielded solutions much more diffusible than those of substances which were not possessed of the power of crystallizing, such as gelatine; hence he has classed substances into *crystalloids* and *colloids.*

How can we explain these phenomena, unless it be admitted that there existed a degree of attraction or adhesion between the albumen and the jelly greater than that occurring between the salt and the jelly—so that in the one case the albumen was fixed in the jelly, while in the other the salt moved freely out of it? Substituting the simpler cases of pure white of egg and a solution of common salt in water, the different degrees of diffusibility exhibited in these two instances will admit of a similar explanation, the water in the white of egg retaining the albumen in one case, and that which was present in the saline solution letting out the salt in the other. If this view be taken of the cause of the various degrees of diffusibility of different solutions, it must be acknowledged that there exists a certain attraction between substances and the water which holds them in solution; and this attraction varies in its degree according to the substance.

I propose, for want of a better denomination, to call this by the name of *colloid* attraction, and to say that the albumen in white of egg is held to the water by 'colloid attraction.' I therefore retain the names *colloid* and *crystalloid* given by Graham—colloids not being possessed of the power of crystallizing, and being sparingly diffusible, while crystalloids are crystallizable substances, yielding readily diffusible solutions.

Crystalloid solutions never gelatinize; colloid solutions either gelatinize or solidify into a thick, gummy, adhesive substance, which dries into a residue exhibiting, frequently, somewhat the appearance of a varnish.

This colloid attraction, which keeps water and isinglass together in molecular union in a jelly, is also apparently concerned in the formation and physical existence of animal tissues. Muscular tissue is formed of fibres running parallel with each other in the form of bundles, which are not in mutual contact, but separated from those in their immediate vicinity by connective tissue. These fibres consist physically of animal matter and water, held together by a peculiar power which cannot be considered due to a chemical property, but appears to exhibit the character of colloid attraction. The present view rests on the following considerations:—

1st. That muscles have a soft pliable consistence, and are dry to the touch as a jelly would be.

2nd. That Kühne, of Heidelberg, has obtained from muscular tissue a real jelly he has called *myosine.*

3rd. That muscular tissue contains a proportion of water which does not appear to vary in health.

4th. That chloride of sodium, in a certain proportion, interferes with the setting of gelatine; and muscular tissue is nearly free from this substance, while blood (which remains liquid) contains it in a comparatively large quantity. And it is worth noticing that when blood loses its chloride of sodium by dialysis (diffusion) it becomes considerably thickened.

5th. That after removing, by dialysis (diffusion) certain diffusible substances which muscles contain in the small proportion of about 25 per 1,000, there remains a mass differing, it is true, from a jelly, in as much as it yields a solution of colloid substances by trituration in water, but like a jelly in the fact that the removal of these colloid substances leaves a material consisting of substances in a semi-solid condition, which are fixed by the water present; no amount of trituration or pounding or squeezing in water will alter the composition of this soft solid mass, which, if it were not for its tenacity and fibrous consistence, would possess in many respects the characters of a jelly, holding certain proportions of albumen and other equally colloid substances.

The fact of there being a fixed proportion of water in muscular tissue is remarkable. The consistence of a jelly depends on the amount of water it contains ; a solution of gelatine in too large a bulk of water will not set at all, while the less water this solution contains the more solid the jelly will be. Now it is but fair to assume that muscles must have a certain fixed consistence for the normal performance of their functions ; and if their consistence depends on the proportion of water present, as in the case of a jelly, muscles must contain a fixed proportion of water, which they really do.

Kühne has succeeded in extracting from the muscles of frogs immediately after death a substance which sets into a firm coagulum.

'If a frog be opened, a 1-per-cent. solution of chloride of sodium driven through the blood-vessels until all the blood is removed, the muscles then rapidly chopped up and subjected to firm pressure, a liquid will be obtained which in a short time sets into a firm coagulum.'—*Myologische Untersuchungen* (extracted from Watts' Dictionary of Chemistry).

Therefore juice of flesh has a tendency to coagulation, as would a solution of gelatine ; this tendency must be possessed by those substances in juice of flesh which are soluble and colloid, and therefore, as I shall show, destined to the nutrition of flesh, or to become transformed into muscular tissue.

I conclude that there is a strong ground for the belief that the elementary physical constitution of muscle is that of a jelly—with this difference, that it is organised so as to possess due tenacity for the performance of its functions ; but the water, albumen, and other constituents hold apparently the same relation to each other as water would to gelatine in a jelly.

Bone may be considered as consisting originally of a jelly of a colloid material and water, the water being subsequently replaced by phosphate and carbonate of lime and magnesia, which are united with the colloid material much in the same way as the water had been originally

united to this same material. The existence of a colloid constituent of bone very much resembling gelatine is easily demonstrated by the well-known experiment of immersing a bone in dilute hydrochloric acid, when the earthy matters are removed, water taking their place and entering into a colloid union with the gelatinous matrix, the union being apparently similar to that which had existed before between the earthy matters and the colloid material. The connexion between water and gelatine in a jelly obviously takes place between two colloid bodies, although water may under certain circumstances, as under the influence of cold, assume the crystalloid condition; and moreover we find that, in the formation of bone, phosphate and carbonate of lime and magnesia exist in an amorphous or non-crystalline state: I therefore consider these earthy substances as existing in a colloid condition in osseous tissue.

Animal tissues, although in some respects resembling a jelly, vary, of course, essentially from this colloid material because of their having a definite structure. Virchow considers from observations with the microscope that there exists in muscular and other tissues a complex system of minute channels, the object of which is apparently to allow of the transmission of the nutritive material to the different parts of the tissues. Indeed it is very difficult, not to say impossible, to account for the distribution of the colloid material destined to nourish tissues after it has left the blood, unless the presence of channels or other intercellular passages be admitted. That such a nutritive material really exists must be acknowledged, as (Quain's 'Elements of Anatomy,' vol. ii.) 'the capillaries destined for the proper tissue of the muscle form among the fibres a fine network with narrow oblong meshes, which are stretched out in the direction of the fibres. . . . . none of the capillary vessels enter the sarcolemma or proper sheath of the fibre.' There must consequently be a material intermediate between blood and tissue, reaching every particle of the tissue to be nourished; and with this object in view, there must exist proper means for the thorough

distribution of this material. I have shown (*Bibl. Universelle*, Feb. 1865), by a very simple observation of a physical nature, and without the use of a microscope, that there exists in muscular tissue a system of intercellular passages containing the material destined to the nutrition of flesh.

On considering the physical condition of flesh, it occurred to me that there would be no difficulty in determining whether muscular tissue is strictly a colloid mass like a jelly or not, by merely immersing a piece of muscle or raw meat in water. Should it be a solid colloid body, no albumen could be expected to diffuse out of the meat into the water; on the other hand, if it was a porous mass, and should these pores or minute channels contain albumen, some of the substance would necessarily pass out of the meat into the water by a process of porous distribution as would take place if a sponge containing white of egg were immersed or hung up in water.

It is an observation nearly of daily occurrence that raw meat steeped in cold water yields albumen. 200 grammes of ox-flesh were minced and extracted with 125 cub. centims. of distilled water, the phosphoric acid and albumen, being subsequently determined in the extract. On the other hand, a piece of raw beef weighing 200 grammes was immersed for 26 hours in 125 cub. centims. of distilled water, when the phosphoric acid and albumen were also determined in the fluids; the result of the analysis showed that although more albumen was obtained by extraction than by the process of infusion, still one gramme of albumen had passed out of the meat into the water in which it was merely immersed. The numerical results were as follows:—

	In 100 cub. centims. extract.	In 100 cub. centims. fluid in which the flesh had been immersed.
Phosphoric acid	0·233	0·169
Albumen	2·925	1·067

Consequently flesh is not a solid colloid body, although formed of colloid molecules, but is permeated in every

direction throughout its mass with a multitude of minute channels charged with the material destined to its nutrition, to which the albumen belonged. It might be objected that a small quantity of blood was possibly left in the tissue after slaughtering, which would account for the presence of albumen in the water in which the meat was steeped; but meat from slaughtered animals is perfectly free from blood. On triturating minced ox-flesh with salt water I could not find any blood-corpuscles by subjecting various portions of the mass to microscopal examination, while on adding one or two drops of serum containing some blood-corpuscles to a few ounces of the pulpy mass, and agitating the whole together, the blood-corpuscles could be detected most readily. In the tissue of the heart of the ox, however, I usually found small quantities of blood, and had to give up determining the albumen in extracts of that organ because of the results being too high on that account. On these occasions I had no difficulty in detecting the presence of blood.

Returning to my subject, I hope to have succeeded in showing that muscular tissue consists of a solid material either porous or permeated by inter-cellular passages containing an albuminous fluid, and that the constituents of the solid material are bound together in every molecule by a force similar to that which connects gelatine and water in a jelly.

ON THE MODE OF NUTRITION OF TISSUES.

A tissue consists of a solid portion containing a fluid nutritive material within its mass. It must appear obvious at the outset that if the solid portion is colloid, the material for its formation must also be colloid; indeed it is well known that albumen, a thoroughly colloid substance, takes a considerable share in the process of nutrition. I shall show that the phosphoric acid, together with the small quantity of potash (and, we may assume, also the magnesia), which enter into the composition of

the nutritive material are also colloid; muscular tissue contains, however, nearly 25 per 1000 of *crystalloid* material, consisting of potash and magnesia salts, and very small proportions of chlorine and soda, together with crystalloid organic nitrogenized substances, such as kreatine and kreatinine. It occurred to me that the formation of these crystalloid substances was due to the process of waste—a view which derived some support (before it was thoroughly investigated) from the fact that the urinary secretion consists of diffusible substances; the transformation of colloids into diffusible crystalloids appeared moreover at the outset a convenient method for a process of elimination; and also, blood holding less crystalloid substances than tissues, could hardly be considered the source of the crystalloid substances the latter contain.

The formation of the nitrogenized crystalloids in tissues would, according to this view, be due, exclusively to a transformation of assimilated albumen with the object of its ultimate elimination. The investigation upon which I now beg to enter, extending over a period of about five years, proved the correctness of this theory. A tissue is constantly undergoing change. Very soon after it attains its highest stage of development or its state of maturity, it dies, and is decomposed into crystalloids. Dr. Beale ('Life, Theories,' &c.) believes that as soon as what he calls the bioplasm is transformed into the insoluble matrix of a cell, it dies, then disappears, and is replaced by other cells.[1] We may therefore regard tissues as formed of three different materials:—(1) the nutritive material which has left the blood and is on its way to become assimilated; (2) the fully developed or ripe tissue; (3) the material resulting

[1] Beale states:—'Every tissue may be divided anatomically into *elementary parts* [sic]. Each elementary part consists of the *living matter* or *bioplasm* and the *lifeless formed matter* (cell-wall, envelope, tissue, inter-cellular substance, periplastic matter) produced at the moment of the death of the particles of the first.' Beale, therefore, apparently considers as dead organized particles what I have called *ripe or mature tissue*, which, however, is on the point of becoming dead and lifeless. It appears to me *mature* because it is in this state only that it can perform its functions.

from the waste of tissues, which is on its way out as effete matter.

After much time and consideration had been devoted to the available means of separating from each other these three different materials and effecting their analysis, I adopted the following process, which answered the purpose most satisfactorily.

If, say, 200 grammes of flesh be minced thoroughly and mixed with 500 cub. centims. of water into a homogeneous pulpy mass, there will be obtained, after straining through calico or muslin, about 500 cub. centims. of extract (including that wetting the calico), while about 154 cub. centims. of solution will remain in the fibrous mass left in the calico. The amount of solution of about 154 cub. centims., is estimated by drying the weighed fibrous mass, the loss of weight so obtained representing the volume of the solution or extract without any material error. The total extract will therefore be equal to very nearly 654 cub. centims., and will contain:—

1st. The whole of the colloid material on its way to form flesh;

2nd. The whole of the crystalloid material resulting from the waste of tissue and on its way out of flesh.

The fibrous portion in the muslin, imagined dry and free from extract, will represent a mass weighing rather less than 46 grms., and consisting of colloid material assimilated and insoluble in water plus a small portion of colloid material in process of assimilation. This partly assimilated colloid material has the same composition as that of the insoluble fibres; indeed I shall be able to show that the whole of the colloid material destined to become assimilated has the same composition as the fully developed and insoluble tissue; so that the passage from fluid to solid is a mere morphological change.

I now beg to state how the composition of the three different classes of materials constituting animal tissues was determined, these materials being classed as follows:—

1st. The fibrous insoluble mass;

2nd. The colloid fluid, destined to form the insoluble mass;

3rd. The crystalloid solution, destined to remove from flesh the effete material it contains.

I must be allowed to enter fully into the particulars of the analysis. 200 grammes of beef were obtained from an ox very shortly after slaughtering. With this object in view, I arranged with a butcher that he should cut out the meat as soon as the bullock was killed, or early next morning, if too late for the analysis to be commenced that same day. The oxen were slaughtered as usual; after being felled with the pole-axe, one or both of their jugular veins was opened, and the blood allowed to run out, so that the capillary vessels of the muscular tissue were quite empty when the flesh was removed for analysis. I frequently obtained the meat quite hot, and in every case it was perfectly fresh. Pieces as free as possible from fat and tendons were dissected out from the mass I received from the butcher, so as to obtain as nearly as possible nothing but muscular tissue. Usually 200 grammes of the flesh so prepared were placed on a chopping-board and minced with a heavy chopper, the mincing being carried on until a nearly homogeneous mass of muscular tissue was obtained. This mass was free from blood, but contained a certain proportion of connective tissue, some fat, which could not be separated by any mechanical contrivance, some empty capillary vessels and nervous twigs.

The 200 grammes of minced muscle was next mixed with 500 c.c. of distilled water in a beaker, and the whole briskly agitated with a glass rod, so as to distribute the mass thoroughly throughout the water; the contents of the beaker assumed the form of a thin pulp. This operation took from ten minutes to half an hour for its completion, but it was seldom less than from a quarter to half an hour before the straining was proceeded with. By that time it was assumed that every particle of meat, which of course

might be considered as surrounded with water, had yielded to the water all its diffusible constituents, retaining those constituents which were not diffusible; the object of the mincing being to tear or cut up the meat into its finest particles, so as to increase to as great an extent as possible the phenomenon of diffusion necessarily occurring after the admixture of the meat with water. The straining was performed either in a piece of calico, or better, in muslin. The strained fluid was collected in a glass measure and its volume determined; the residue in the cloth being next carefully transferred to a weighed capsule, when its weight was at once ascertained. The capsule and its contents were placed on a water bath, and finally in an air bath at a temperature slightly over 100° C. After complete desiccation the capsule and dry fibres were weighed, and the weight of the dry fibrous mass thus ascertained. The wet cloth or muslin which had been used for straining the minced meat, was weighed, dried in an air bath, and again weighed, in order to determine the weight of the water it had retained.

The weight of the water in the fibrous mass was considered as representing the volume of the extract retained by the fibres of the minced flesh after straining. By so doing, a slight error was committed, as the extract consists of water holding substances in solution and not of pure water; these substances in solution, however, occupy very little space; so much so that I have determined experimentally that the error may be disregarded. It would have been easy to correct this error, had I deemed it advisable, by determining the water in the extract, but the necessary operations in the present investigation were so numerous and the manipulations required so much time and labour, that it was of importance to simplify the method of analysis as much as possible. The extract or fluid from the fibrous mass after straining was not quite clear; and on that account it was filtered through filtering paper, when a red clear port-wine coloured solution was

obtained. Thirty cubic centimetres of this fluid were used for the determination of albumen and of the nitrogen present in addition to that contained in the albumen; the operation was conducted as follows:—

The Extract—Determination of Albumen.—The 30 c.c. of extract were mixed with as much or more water in a platinum capsule, and boiled. After boiling briskly for a few seconds the fluid was evaporated to dryness in a water bath, the residue was washed with hot distilled water, then hot alcohol, and finally a mixture of alcohol and ether, the washings being all run through the same filter. Finally, the albumen in the filter was washed back again into the platinum capsule with as little water as possible, and the whole albumen was dried, weighed, and incinerated, when a very small proportion of ash was obtained; the difference between the weight of the capsule and its contents, before and after incineration, gave the weight of the *albumen.*

This method yielded very satisfactory results, as will be seen by the fact that two equal quantities of the same extract of flesh yielded as near as possible the same weight of albumen. Two determinations of albumen in the same extract were frequently made in order to ensure the accuracy of the result. I beg to subjoin the numbers obtained in some cases, taken, I might say at random, from my notebook, and which will show how closely the results agreed:

Albumen in 30 c.c. Extract	Ox Flesh	Ox Flesh	Salmon	Ox Lungs	Ox Lungs	Ox Lungs	Human Tubercular Lungs	Human Tubercular Lungs	Human Tubercular Lungs	Human Tubercular Lungs
1st determination	0·248	0·243	0·578	0·582	0·625	0·5585	0·338	0·310	0·2175	0·296
2nd determination	0·250	0·239	0·570	0·586	0·632	0·558	0·342	0·310	0·2145	0·297
Mean . .	0·249	0·241	0·574	0·584	0·629	0·558	0·340	0·310	0·206	0·296

Out of the ten analyses, the greatest difference between two determinations of albumen in 30 c.c. of the same ex-

tract amounted to only 0·008, or 1·4 per cent., while in two cases the results were identically the same; the mean difference between the results respectively in the ten analyses amounted to only 0·003, equal to about 0·7 per cent. of the albumen. It was very important to obtain accurate determinations of albumen, as it will be seen that the amount of this substance present in a given weight of tissue rules the proportions of phosphoric acid and potash (colloid) in the nutritive fluid contained in that same weight of tissue.

The filtrate from the 30 c.c. of extract after separation of the albumen, together with the whole of the washings, was evaporated to dryness after admixture with a little sulphate of lime. The residue could be easily scraped off from the glazed porcelain capsule which held it, and in this condition it was burnt with soda lime in a combustion tube for the determination of the nitrogen it contained. This nitrogen, which was clearly all the nitrogen present besides that contained in the albumen, calculated into albumen, represented the amount of albumen in the tissue in course of *elimination*, while the weight of coagulable albumen was considered as that which was in course of *assimilation*; and the correctness of this view will be proved, I trust, to the complete satisfaction of the reader.

Determination of Phosphoric Acid and Potash.—Most (a measured quantity) of what was left of the extract, after the separation of the amount required for the determination of the albumen, had to be evaporated to dryness and incinerated. The incineration was conducted with the greatest possible care. After being slowly carbonized, the charcoal obtained was ground and washed repeatedly on a filter with distilled water acidulated with hydrochloric acid. The filter and carbonaceous residue were finally burnt in a platinum capsule and the ash dissolved in the acidulated fluid. By so doing every precaution was taken to avoid losing any of the constituents of the ash by volatilisation from the heat which would have been necessary to the complete oxidation of the carbon.

The solution of the ash in dilute hydrochloric acid was usually made up to 250 c.c., of which 50 or 75 c.c. were taken for the determination of phosphoric acid and another portion for that of the potash. The remainder of the solution was carefully preserved in a bottle labelled, in case the analysis should have to be repeated.

The estimation of the phosphoric acid was done with acetate of uranium, ammonia, and acetic acid, weighing the precipitate. A number of preliminary experiments convinced me that the volumetric method, with a salt of uranium, although much more rapidly executed than the weighing process, was not sufficiently correct for my purpose, as the greatest degree of accuracy was indispensable towards the object I had in view. Some doubts occurred in my mind as to whether the phosphoric acid was precipitated completely by means of uranium from a pyrophosphate as well as from a tribasic phosphate, as the presence of a pyrophosphate in the solution was quite possible. I set to work to investigate this point, and after a number of determinations of phosphoric acid from a solution of pyrophosphate of magnesia prepared by igniting the ammoniaco-magnesia phosphate, I arrived at the conclusion that phosphoric acid was completely precipitated from a pyrophosphate by means of uranium.

The determination of the potash was effected by precipitating the phosphoric acid and magnesia by means of a solution of caustic baryta as pure as I could obtain it. This baryta contained, however, a little soda, which was estimated with the view to making the necessary correction. After separation of the baryta precipitate, the fluid was evaporated to dryness, and the residue was decomposed by means of oxalic acid, and the application of heat according to Field's process; the whole of the chlorine was thus evolved, and the alkalies transformed into carbonates. The carbonates were next converted into chlorides, which were weighed, the potash was estimated with bichloride of platinum in the usual way.

The Fibrous Residue.—The fibrous residue left after the separation of the extract of the minced tissue, was dried for the estimation of the water it contained, and then incinerated, with the exception of a small portion which was reserved for the determination of the nitrogen. The incineration was conducted with the same precautions as those taken in the case of the incineration of the extract, and the phosphoric acid and potash present were determined precisely in the same way as in the case of the extract. The nitrogen was estimated in the dry fibrous mass by combustion with soda lime. There might have been a very small loss of nitrogen by adopting the present plan, but this substance formed such a large proportion of the fibrous residue, that a very slight loss, if it had been committed, could safely be overlooked as exerting no material influence on the ultimate result.

The Calculation of the Results.—The calculations required for establishing the results of the analysis in such a form as to explain the phenomenon of the nutrition of the tissue under consideration, were as follows.

The nitrogen in the total fibrous mass obviously represented collectively, 1. The nitrogen belonging to the completely assimilated tissue; 2. The nitrogen belonging to the soluble and coagulable albumen retained in the mass; 3. The nitrogen belonging to the crystalloid products of decomposition of albumen, such as kreatine and kreatinine, which had also been retained in the fibrous mass. The amount of soluble coagulable albumen present was found by calculating the following proportions:—If 30 cubic centimetres of the extract contain a certain quantity of albumen, how much albumen will the water (considered as extract) retained in the fibrous mass contain?

2. The nitrogen crystalloid, or the whole nitrogen present besides that belonging to the coagulable albumen retained in solution in the fibrous mass, was calculated precisely in the same way, and expressed in its proportional weight of albumen. These two numbers representing the amount of albumen coagulable and albumen calculated from

the remaining of the nitrogen present in the extract, after separation of the true albumen, were added to each other, and the sum was subtracted from the nitrogen present in the total fibrous mass expressed as albumen. By this means I obtained the proportion of nitrogen assimilated, expressed as albumen, in a given weight of tissue.

The phosphoric acid and potash belonging to the mature tissue were calculated precisely in the same way as the albumen; the proportions of these substances in the extract, retained by the fibrous mass, being subtracted from the total quantity of these same substances respectively in the fibrous mass, gave their proportion in the mature tissue.

The composition of the nutritive fluid was calculated as will be explained hereafter, and that of the effete or crystalloid material was represented by the proportions of the substances in the mature tissue and nutritive material added together two by two, and subtracted from the total amount of each of these substances in the flesh analysed.

A simple way of explaining this will be as follows. Let the albumen, phosphoric acid, and potash be represented respectively:—

In the insoluble fibrous mass by

$$A, \quad B, \quad C;$$

in the soluble colloid material by

$$A', \quad B', \quad C';$$

in the total flesh by A'', B'', C'';

in the crystalloid material by

$$A''', B''', C'''.$$

B' and C' are calculated by the following proportions:—

$$A : B = A' : B',$$
$$A : C = A' : C'.$$

The crystalloid material has also to be calculated,

$$A''' \text{ being } = A'' - (A + A'),$$
$$B''' \qquad = B'' - (B + B'),$$
$$C''' \qquad = C'' - (C + C').$$

Example.—For instance, 300 grammes of muscular tissue from a salmon yielded, with 750 c.c. water,

Extract . . .	978 c.c.
Dry residue . .	60·6 grammes.
Water in fibrous mass	237 c.c.

30 c.c. of the extract were found to contain 0·574 grammes albumen, and 0·2006 albumen calculated from the nitrogen present in the filtrate from the coagulated albumen. The proportions calculated were as follows:—

$30 : 0{\cdot}574 = 237 : X$	$X = 4{\cdot}534$
$30 : 0{\cdot}2006 = 237 : X$	$X = 1{\cdot}585$
Coagulable and non-coag. albumen in solution in fibrous mass	6·119 or 6·12.
Total albumen in fibrous mass, calculated from the nitrogen present	43·86
	− 6·12
	37·74

of which one-third is to be subtracted, as the results are invariably expressed for 200 grammes of tissue, yielding 25·16, this number representing the weight of *albumen assimilated* in 200 grammes of salmon submitted to analysis.

The phosphoric acid in the total fibrous mass was found to be 0·6105 grammes; while 650 c.c. of the extract yielded 0·969 grammes of phosphoric acid; consequently $650 : 0{\cdot}969 = 237$ (extract or water retained in the fibrous mass) $: x = 0{\cdot}354$ phosphoric acid in the extract retained in the fibrous mass. This has to be subtracted from the phosphoric acid found in the total fibrous mass; thus, $0{\cdot}6105 - 0{\cdot}354 = 0{\cdot}2565$ phosphoric acid assimilated or forming part of the mature or fully developed muscular tissue. Calculated for 200 grammes of tissue this number becomes reduced by one-third, and equal to 0·171.

The potash in the total fibrous mass was found to amount to 0·4104, while by a calculation precisely similar in every respect to that for estimating the phosphoric acid, the potash in the 237 c.c. of extract retained in the fibrous

mass was found to amount to 0·3125 grammes, therefore $0·4104 - 0·3125 = 0·0979$ potash; or for 200 grammes of salmon 0·0653 potash.

The nutritive fluid, the object of which was to become transformed into the mature tissue by a process of assimilation, could have, it was assumed, no other but the same composition as that of the fully developed tissue; and as the proportions of phosphoric acid and potash were necessarily regulated by the amount of soluble albumen present in a given weight of the tissue, the theoretical composition of the nutritive fluid had to be calculated by means of the following proportion:—If 25·16, the amount of albumen assimilated in 200 grammes of salmon-flesh, correspond to 0·171, the amount of phosphoric acid assimilated in 200 grammes of salmon, to how much phosphoric acid will correspond 12·47, the amount of true soluble albumen in 200 grammes of salmon. The result of the calculation is 0·085, which represents the amount of phosphoric acid colloid belonging to the nutritive fluid of 200 grammes of salmon. A similar rule of three will yield the amount of potash belonging to the nutritive fluid. This will be $25·16 : 0·065 = 12·47 : x. \quad x = 0·032.$

Finally, the composition of the effete matter, consisting of substances undergoing elimination, or on their way out of tissue, was determined by a very simple process. The albumen, transformed into crystalloid in 310 grammes of salmon with the view to its removal by diffusion, was found to be 6·54, or for 200 grammes of flesh 4·36 grammes. This number was originally obtained by determining the nitrogen in the filtrate from the coagulated albumen in 30 c.c. of the extract, and calculating the result for the whole extract, including the portion retained in the fibrous mass. The nitrogen found was then expressed in the quantity of albumen which would correspond to it. The phosphoric acid effete or crystalloid, was calculated by subtracting the quantity of phosphoric acid colloid belonging to the nutritive fluid, amounting to 0·085, from the total quantity of phosphoric acid found in the whole of the extract,

including that portion of the extract which was retained in the fibrous mass, amounting to 0·972 for 200 of flesh. The result of the subtraction gives 0·887 as the amount of phosphoric acid effete in 200 grammes of salmon flesh. The potash effete was calculated precisely in the same way as the phosphoric acid effete, viz., the potash found in the whole of the extract amounted to 1·29 or 0·860 grammes for 300 of flesh, from which 0·032, the quantity of potash in the nutritive material, was subtracted, leaving 0·825 for the amount of potash effete.[1]

The above particulars, into which I have thought it advisable to enter, will give, I trust, a clear idea of the method of investigation adopted, and of the various stages of the analysis.

I now wish to point out clearly what is *fact* and what appears *theoretical* in my results, and having done this I hope I shall be able to prove satisfactorily that what appears as a theory is really not a theory but a fact.

I trust nobody will impugn the correctness of the determinations, which were made with great care, after I had devoted a considerable time to the examination of the various methods of analysis which were available, in order to select those I found most trustworthy and exact. I may add that all my early determinations, which were made before I had satisfied myself as to the best means of proceeding, were altogether rejected, a considerable amount of work being thereby mercilessly set aside.

The numbers showing the constitution of the material forming the mature and insoluble tissue are obtained directly by analysis. The tissue is so thoroughly minced and mixed with water before extraction that there cannot be any doubt as to the water being distributed quite equally throughout the whole mass, and consequently the proportion existing between the water and solid matter in the extract (fluid) must be the same as the proportion existing between the water and solid matter of that portion of the extract which

[1] For the results of this analysis in a tabular form, see page 35.

is retained in the fibrous mass after straining. Therefore knowing the amount of albumen, phosphoric acid, and potash, and the amount of water in the extract or the volume of the extract, the quantity of albumen, phosphoric acid, and potash contained in the portions of the extract retained in the fibrous mass after straining can easily be calculated after ascertaining the amount of water contained in the mass. On the other hand, the composition of the portion of tissue and extract left on the muslin having been determined, it is obvious that by subtracting from the total quantity of albumen found in the mass, the weight of the soluble and coagulable albumen, added to that of the albumen calculated from the nitrogen, contained in the portion of the extract retained in the mass, and operating in a similar way for the phosphoric acid and potash, the result of the subtraction will show the composition of the tissue insoluble in water. So far there can be no theoretical result.

If in the present investigation I have attempted to reduce tissues into the substances which compose them, and to constitute tissues afresh theoretically or rebuild them by classing their constituents in a physiological form, or in the same form as that which I believe they assume in the tissues, I do not wish for a moment to depreciate the great value of the microscope as a means of investigation in physiology. The instrument in such hands as those of Kölliker, Charles Robin, Carpenter, Beale and Sanderson claims a full acknowledgment of services rendered towards the progress of physiological knowledge.

The microscope reveals structures, but not the substance of which those structures are composed. It has enabled Dr. Beale and other observers to trace the so called germinal matter into the interior of organized cells, but has thrown no light upon the composition of this germinal matter. We are aware that tissues waste away and are made up afresh in the process of nutrition, without there being any break of continuity, but we do not

know how this phenomenon takes place, and surely it is of the highest interest and importance in a biological point of view that this subject should receive attention. Are we to ignore it because it does not appear at first sight how we should undertake the investigation? and if chemical analysis should lend its aid towards the elucidation of this subject, surely chemical means of investigation calculated to attain this end are deserving of every consideration. But the physiologist now steps in with an objection plausible at first sight. He will observe, that even admitting tissue to be free from blood, still it consists of a number of different anatomical elements interwoven and inseparable from each other, for instance flesh will be formed of muscular fibres, connective tissue, fat, nervous twigs, and vessels; and he will object to my work on the ground that I cannot separate physically the various portions of tissue, and analyze them. To this I reply—fat which forms but about 2 per cent. of the weight of muscular tissue (Liebig's 'Chemistry of Food'), and is perhaps its main constituent by weight, besides the muscular fibres, is entirely set aside by its non-nitrogenous character and the mode of investigation I have adopted, and consequently I do not consider at all this portion of flesh in my analysis. Moreover, I must observe that the nutritive material for a muscle exists under the form of a fluid immediately derived from the blood moving through the tissue, and coming in contact with every one of its molecules, so that the various portions of tissue have to take from this same fluid the material they require for their nutrition. The nerves and blood vessels, the connective tissue and contractible tissue have all to help themselves by taking a molecule of their own substance from this fluid, for every molecule that wastes away. It may therefore appear at first sight unphilosophical to place in a tabular form the constituents of the nutritive material of muscular tissue, considering the diversity of objects of that material.

The table in question, however, must be considered as applying to muscles collectively, as I am able to state from

my inquiry that the elimination of muscular tissue *as a whole* yields a definite chemical compound, viz., phosphoric acid and potash, in the proportion of 43 of the former to 57 of the latter, which is that of a pyrophosphate; or in other words, that the whole of the phosphoric acid in the waste bears the above relation to the whole of the potash contained in this waste; considering also, on the other hand, that these numbers are obtained by assuming an uniform nutrition of muscular tissue taken collectively, I infer that it is correct to conclude that the nutrition of tissues may be considered as a whole. Let us suppose that muscular tissue consists of an aggregation of different structures entering in different, though material, proportions, by weight, in the formation of the tissue, and that each of these different structures undergo a distinct and special mode of nutrition. It would, it appears to me, be impossible, or at all events incredible, that the substances resulting from the waste of so many different structures undergoing, each of them, a special mode of nutrition, should actually always bear the same proportion to each other, and this is what really happens with respect to the potash and phosphoric acid. Moreover, it would be still more extraordinary if these two substances were actually present exactly in the right proportion for the formation of a definite compound. I think it is, therefore, safe to conclude that, although there are many structures in flesh, the chemical phenomena of nutrition of these different structures must be considered as a whole, and as their having one object common to them all—that of forming ultimately definite crystalloid compounds.[1]

Returning to my subject, after offering an apology for this digression, I must be allowed to observe that by preparing an extract of a tissue by simply mincing and

[1] I must admit there is still here a missing link. Do the fibres in muscle form such a considerable proportion of the whole mass that chemically the other tissues in flesh fall into insignificance; or do these tissues (fats excepted) possess the same mode of nutrition as the fibres, are questions which remain to be solved.

treating with water, its molecular structure is in no way altered. A tissue may be considered as consisting of a framework entirely insoluble in water and holding imbibed within it the material destined to its regeneration, together with the material into which that framework is decomposed with the view to its elimination. The substances the framework of a tissue contains within its meshes must be in a position to move about freely, and consequently exist in such a condition that water will dissolve them readily. After thorough physical disintegration of the tissue by mincing, the framework must still be insoluble and possess the tenacity and elasticity characteristic of cellular and fibrous structures; its composition first attracted my attention, and its analysis was effected, after much consideration, by the method I have described above.

The existence of this framework can be no theory; it must be matter of fact. It is very interesting to consider how the nutritive material stands in relation with this insoluble portion of tissue. I believe the change is a slow one. The nutritive material finds its way into the organised cells where it becomes protoplasm or germinal matter. This protoplasm is not yet insoluble, but becomes so, *pari passu*, as the fibres or cellular bodies waste away, taking their place. As soon as the protoplasm has undergone this transformation, a fresh amount of nutritive material has found its way into the cells, and so on, there being a nutritive current into the organic cells, while another current is going on from the cells outwards. The germinal matter has chemically the same composition as the nutritive fluid which moves through the mass of tissue, but it is a stage nearer to perfect assimilation. Finally the cells and fibres, which I consider as mature tissue, have the same chemical composition as that of their germinal matter, and as the nutritive material from which this germinal matter originates. Strictly speaking, there may be a slight difference between the composition of nutritive material and that of germinal matter in the same tissue, because

the nutritive material supplies the nutrition of so many different anatomical elements in that tissue; but chemistry cannot yet determine this difference if it really exists, although it proves that, considered as a whole, the nutritive material, germinal matter, and mature tissue all have the same chemical composition, the only difference being that the atoms appear to become packed together closer and closer as the tissue ripens, being nearer to each other in the germinal material, or protoplasm, than in the nutritive fluid, and still more so in the riper portion of tissue.

The nutritive material next claims our attention. Its composition as entered into the table was originally theoretical. I had concluded with, I think, every appearance of truth, that as the only object of the nutritive material was the formation of the framework alluded to above, the amount of phosphoric acid and potash in the nutritive material could be readily calculated on the assumption that there existed the same relation between them individually and the coagulable albumen, as had been found between the phosphoric acid and potash in this framework and its albumen (calculated from the nitrogen found). Now, the composition of the nutritive material, or germinal matter, thus calculated from the coagulable albumen determined by experiment, turned out to be *the true composition of the material.* This was shown to be the case, because, in the investigation of the composition of muscular tissue, by subtracting the theoretical colloid phosphoric acid from the total phosphoric acid in the extract or soluble portion of the tissue on one hand, and by subtracting the theoretical potash from the total potash in the extract on the other hand, the result of these operations yielded two numbers, exhibiting the proportion of 43 to 57. These numbers are precisely those required for a pyrophosphate of potash. The proof of the correctness of my whole theory hinges nearly altogether on the correctness of this result for the composition of muscular tissue, which was only obtained after very great labour.

In accordance with this theory, the albumen, phosphoric acid and potash in the extract of flesh were partly colloid and partly in a crystalloid form; if such was really the case, by dialyzing the extract of muscular tissue, and submitting to analysis the colloid and diffusible portion of the extract, a result should be obtained similar in every respect to that which had been arrived at theoretically.

Now, by submitting to dialysis for twenty-four hours minced flesh made into a pulp with water, the proportions of albumen, colloid phosphoric acid and colloid potash were found in the following analysis very much the same as those obtained for the albumen, phosphoric acid, and potash, either in the mature tissue or in the theoretical colloid (nutritive) material:—

Total Colloid Constituents of 200 grammes of Ox-flesh prepared by Dialysis			Mean Composition of the Mature Tissue Calculated for 5·74 Albumen
		Proportion calc. for 5·74 Albumen	
Albumen (determined as nitrogen)	38·06		
Phosphoric acid	0·375	0·056	0·051
Potash	0·132	0·020	0·017

In this analysis the colloid substances contained in solution in juice of flesh plus these same substances as constituents of the insoluble fibrous mass, bore to each other respectively very nearly the same proportion as the constituents of the mature or insoluble tissue.

In another experiment the albumen, non-albuminous nitrogen and phosphoric acid were determined in the extract, while the phosphoric acid and non-albuminous nitrogen were also estimated in the diffusate of the dialysed extract. The nitrogen, calculated afterwards as albumen, and phosphoric acid, were also determined in the flesh after extraction. 200 grammes of ox-flesh were extracted with 500 c.c. of water.

—	Mature Tissue	Nutritive Material	Waste
Albumen	30·95	5·60	3·408
Phosphoric acid	0·177	0·032	0·495

Found by dialysis.

Colloid or Non-diffusible			Crystalloid or diffusible
Albumen	Coagulable[1] .	5·60	3·261
	Non-coagulable	0·150	
Phosphoric acid . .		0·022	0·504

In this experiment only 4·3 of albuminous waste (crystalloid) in 100 parts had failed to pass through the septum of a dialyzer after 36 hours; while 5 per cent. more phosphoric acid than was found as waste had passed through the septum of the dialyzer after the same lapse of time; this small proportion of phosphoric acid probably consisted of some of the so-called *nutritive phosphoric* acid, which not being possessed of such very undiffusable properties as albumen, had traversed the dialyzer's diaphragm. The phosphoric acid left in the dialyzer is too low, which bears out this explanation. Of course the number 0·022 of colloid phosphoric acid found by dialysis will hardly compare chemically with 0·032—the phosphoric acid colloid theoretical; but when the difficulty of the work, and the uncertainty of quantitative analysis carried on by means of dialysis are taken into consideration, the nearness of these two numbers must carry much weight towards the object I have in view.

I should be induced to think that the nitrogenised substances present, besides albumen, undergo *gradually* the crystalloid metamorphosis, which would account for small quantities of these substances failing to pass through the diaphragm of a dialyzer after twenty-four or thirty-six hours. It must be borne in mind, however, that the method of analysis by means of a dialyzer can only be considered as yielding approximate results.

It follows from these experiments that the direct method of analysis—that which might be considered as yielding conclusions independent of theory, but which un-

[1] This albumen is considered as strictly undiffusable, and is entered in the proportion obtained by coagulation in the extract.

fortunately is the least correct—gives results which compare sufficiently closely with the results obtained by theory, to confirm the correctness of this theory.

I shall not take into account my earliest analyses, amounting to fourteen in number, which are incomplete in several respects. Moreover the methods of analysis then adopted were not nearly so correct as those with which the subsequent inquiry was conducted. I have to report seven analyses of muscular tissue.[1] For the first four the flesh was taken from the muscles of the neck of as many oxen immediately or but very few hours after slaughtering. For the last three analyses, the muscular tissue was obtained at the Consumption Hospital (Brompton) from human subjects after death from phthisis, before decomposition had set in. The composition of these last three samples (four with the additional analysis), varied but slightly from that of the other four; and the result respecting the phosphoric acid and potash effete was precisely the same. I shall at present consider only the first four analyses.

[1] An eighth analysis of muscle after death from phthisis is added at p. 43.

Table showing the Constituents of Muscular Tissue in 200 grammes.

	I.		II.		III.		IV.		Mean
	In 200 grms. Ox-flesh	Proportion	In 200 grms. Ox-flesh	Proportion	In 200 grms. Ox-flesh	Proportion	In 200 grms. Ox-flesh	Proportion	In 200 grms. Ox-flesh
Class No. 1. Composition of the material forming the mature and insoluble Tissue.									
Albuminous material	31·16	100	27·216	100	26·6	100	27·3	100	28·070
Phosphoric acid	0·189	0·606	0·239	0·88	0·3	1·13	0·276	1·01	0·251
Potash	0·054	0·173	0·017	0·06	0·244	0·94	0·03	0·11	0·086
Magnesia	—	—	—	—	0·423	1·6	0·509	1·86	—
Class No. 2. Composition of the material destined to become Flesh, entirely Colloid.									
Albuminous material	6·62	100	5·67	100	5.265	100	5·428	100	5·745
Phosphoric acid	0·04	0·604	0·050	0·882	0·060	1·13	0·055	1·01	0·050
Potash	0·011	0·166	0·003	0·053	0·048	0·91	0·006	0·11	0·017
Magnesia	—	—	—	—	0·009	1·7	0·049	0·18	—
Class No. 3. Composition of the effete material on its way out of Flesh, entirely Crystalloid.									
Albuminous material	3·64	100	3·622	100	3·622	100	3·913	100	3·70
Phosphoric acid	0·595	16·34	0·62	17·12	0·518	14·3	0·521	13·31	0·563
Potash	0·762	20·93	0·803	22·17	0·723	19·96	0·759	19·69	0·761
Magnesia	—	—	—	—	0·025	0·69	0·0955	2·44	—

	Found.				Mean found.	In 100. $2KO.PO^5$. Theory.
Phosphoric acid	43·8	43·7	41·7	40·4	42·4	43·0
Potash	56·2	56·3	58·3	59·6	57·6	57·0

I shall now beg to offer a few additional remarks on the mature fibrous and insoluble material, and on the effete crystalloid constituents of flesh.

I. *The insoluble fibrous material.*

It is this part of muscular tissue which may be considered as giving muscles their tenacity and contracting power. It is formed of molecules disposed according to a certain definite structure, and consisting of albumen, phosphoric acid, potash, and magnesia, which, however, do not exhibit fixed proportions, but vary within certain limits. These molecules are constantly undergoing destruction, and may be considered as dying very shortly after they are ripe.

The regularity with which the nutrition of this mature portion of flesh takes place is strikingly shown by the fact that the soluble and coagulable albumen in a given weight of tissue always bears the same proportion to that of the albumen, assimilated in the insoluble fibrous mass. The absolute quantity of albumen assimilated in a given weight of muscle varies, probably, in a greater measure, on account of the different proportions of fat muscle it contains; but the relation of this assimilated albumen to the soluble and coagulable albumen remains very nearly the same in every case, as shown in the following table:—

Found in 200 grammes of Ox-flesh		In 100	
Albumen Insoluble	Albumen	Albumen Insoluble or Organised	Albumen Soluble
Analysis I. 31·16 . .	6·62	82·48	17·51
,, II. 27·216 . .	5·67	82·76	17·24
,, III. 26·6 . .	5·265	83·48	16·52
,, IV. 27·3 . .	5·428	83·40	16·60
Mean . . .	—	83·04	16·97

From which results the fact, that for *every molecule of albumen assimilated or converted into insoluble muscular tissue, an equal quantity of albumen is withdrawn from blood into the tissue.* This mean propòrtion of soluble to insoluble (or assimilated) albumen is as 16·97 to 83·14, or 1 to 4·9, which means that there is 4·9, say 5 times as much assimilated albumen in flesh as in its nutritive fluid.

II. *The effete material on its way out of flesh entirely crystalloid.*

This includes perhaps the most interesting results from my inquiries.

I shall first beg to draw attention to what I have called *the effete albuminous material,* and compare it with the corresponding constituent of the fluid destined to nourish flesh. What I have considered as the albuminous material of the third class is crystalloid, having assumed the form of kreatine, kreatinine, &c. Notwithstanding the variety of substances into which albumen is thus transformed, we find a relation between the albuminous materials of both classes which does not vary between wide limits. Thus:—

	Albumen Coagulable and Colloid, 2nd class	Material from Albumen Crystalloid, 3rd class	Relation
	6·62	3·64	1·82 : 1
	5·67	3·622	1·57 : 1
	5·265	3·622	1·45 : 1
	5·428	3·913	1·30 : 1
Mean .	5·746	3·699	1·56 : 1

Hence the nutritive fluid of flesh contains a mean of rather over one half more albumen than is present in the solution of the effete material. Now it is obvious that if a muscle should retain a certain composition, which it does within certain limits, it must draw upon the blood in proportion to its waste. Therefore for every 3·699 grammes of albumen (in the crystalloid form) on its way out, 200 grammes of flesh must draw 3·699 grammes of albumen colloid and coagulable from the blood. But we find 200 grammes of muscular tissue to contain a mean of 5·746 grammes of colloid coagulable albumen; and as the albumen must regulate the supply of the other substances muscular tissue requires for its nutrition, it follows that about one-third of the whole of the nutritive material present in flesh appears to be in store, not being required for immediate use. Therefore if the blood, from want of food, were incapable of nourishing flesh, yet the muscle would ap-

parently continue, for a certain time, deriving food from the material accumulated within the tissue. This appears to be a provision of nature to allow of muscular exercise during prolonged fasting. Of course this view must be considered a mere deduction open to future investigation.

The relation of phosphoric acid and potash to albumen in the third class varies in the different analyses, the former between 13·31 and 17·12 per cent. (of the albumen), and the latter between 19·80 and 22·17 per cent.; but it is highly interesting to observe that phosphoric acid and potash, relatively to each other, are present in muscle as effete material precisely in the proportion of 43 of phosphoric acid to 57 of potash, corresponding to pyrophosphate of potash, which may be originally the neutral tribasic phosphate of potash subsequently decomposed by incineration. These four analyses all yield a similar result, which will be found confirmed by the composition of the human muscles subjected to analysis.[1] This result is the discovery of the existence of phosphoric acid and potash in the effete material exactly in the right proportion for the formation of *pyrophosphate of potash.*

I believe this is the first time the composition of an inorganic chemical compound has thus been determined by bringing together its constituents, theoretically, in an animal tissue. The formation of this substance is very remarkable; it shows beyond a doubt that blood yields, besides albumen, phosphoric acid, and small quantities of potash and magnesia to be transformed into flesh a large proportion of potash the only object of which is the removal of the phosphoric acid of the ripe muscular tissue. Potash may also be concerned in the oxidation of the albuminous portion of the tissue into crystalloid compounds; and I may remind the reader that Dr. E. A. Parkes has shown that potash taken into the body favours oxida-

[1] The proportions of phosphoric acid and potash effete in human muscular tissue after death from phthisis were as follows in four analyses:—

	Analysis I.	II.	III.	IV.	Mean.
Phosphoric acid	43·2	42·9	42·7	42·8	42.9
Potash	56·8	57·1	57·3	57·2	57·1

tion, causing an increased elimination of urea and sulphuric acid.[1]

The proportions of the constituents of flesh I have introduced under class No. 3 are originally derived from the composition of the extract, from which are subtracted respectively the proportions of the colloid substances present. These colloid constituents are calculated from the composition of the insoluble fibrous portion of the tissue and the proportion of the soluble albumen; so that any error in any one of the determinations of albumen, phosphoric acid, or potash would suffice to vitiate the whole of the result.

ABSENCE OF SODA AND CHLORINE FROM RIPE MUSCULAR TISSUE, OR THE INSOLUBLE PORTION OF FLESH.

The proportions of chlorine and soda contained in juice of flesh are very small; in eleven analyses of the extracts from the flesh of as many different animals, the proportions of chlorine in 200 grammes varied from 0·094 to 0·212. These results may be considered correct, notwithstanding their being represented by such low numbers. They were obtained by the dialysis of a certain bulk of the extract, and determined volumetrically in portions of the fluid outside the dialyzer, being finally calculated for the whole bulk of the fluid in and out of the dialyzer.

The proportion of soda present varied in six analyses from 0·155 to 0·333 gramme in 200 grammes of flesh submitted to analysis, being about twice as much as the chlorine would require to be made into chloride of sodium. Some of the soda is therefore eliminated in combination with one or more of the organic acids resulting from the decomposition of the organic portion of flesh.

My present object, however, is mainly to show that chlorine and soda take no part in the actual formation of flesh. With this object in view, 300 grammes of sheep's flesh were minced and extracted with 750 cub. centims. of water, as usual. The fibrous mass and dry extract were incinerated

[1] British and Foreign Medico-Chirurgical Review, v. 14, 1854.

slowly with pure lime, and the ash was mixed with water, in which the chlorine was determined volumetrically.

The extract retained in the fibrous mass yielded (by calculation) 0·032 gramme of chlorine, and the fibrous portion and extract together 0·035 gramme of chlorine—the difference amounting to 0·003, or 0·001 gramme per 100 grammes of flesh, which is insignificant, and proves the absence of chlorine in the ripe or insoluble tissue.

The experiment relating to the *soda* was undertaken by mincing 200 grammes of ox-flesh, adding water to the mass, and dialyzing the whole for twenty-four hours. The soda was then determined in the diffusate; and the amount of diffusible soda retained in the colloid portion was calculated from the volumes of the fluids in and out of the dialyzer, assuming that the soda had diffused proportionally to the volumes of fluid. The total diffusible soda was now subtracted from the soda found in the total colloid mass—the difference amounting to only 0·004 gramme, or 0·002 gramme per 100 grammes of flesh, which is insignificant; and I conclude that the ripe or insoluble muscular tissue contains no soda. The object of the presence of chloride of sodium in flesh appears to me to be connected with the distribution of water throughout the tissue. This would be a subject interesting to investigate, and likely to yield important results.

ON THE CONSTITUTION AND NUTRITION OF THE MUSCULAR TISSUE OF FISH.

My inquiry on the nutrition of the muscular tissue of fish is limited to an analysis of salmon's flesh, which has yielded the following results :—

Composition of Salmon's Flesh, in 200 *grms.*

	Composition of Insoluble Tissue	Composition of Nutritive Material	Composition of Effete Material
Albumen . .	25·16	12·470	4·360
Phosphoric acid	0·171	0·085	0·945
Potash . .	0·065	0·032	0·828
Soda, total found	—	—	0·058

	Effete, in 100 parts.	Theory.
Phosphoric acid . .	53·3	43
Potash	46·6	57

In the present case the proportion of albumen of the nutritive material is no less than twice as large as in ox-flesh; and about two thirds of the amount of this substance present was in excess of that required for immediate use. The necessity of this large store of nutritive material in salmon's flesh may be accounted for by a consideration of the rapid growth of the fish, amounting in a few months to several pounds during their migration to the sea. (I could not ascertain where the fish was taken.)

The high proportion of phosphoric acid and potash in the effete state is a remarkable circumstance, considering that salmon is constantly subjected to loss of substance from liquid diffusion; but this is explained by the fact that phosphoric acid and potash in salmon, in the effete condition, are not present in the exact proportion to make a crystalloid potash salt; there is an excess of phosphoric acid present; and therefore it may be concluded that these substances are less crystalloid and consequently less diffusible than in the higher class of animals.

These considerations require following up, which it is not my purpose to do at present. My principal object in introducing this last table is to show, in the usual form adopted, the results of the analysis which has been followed out, in detail at pages 18 and 19, as an illustration of the method pursued in the whole inquiry.

ON THE NUTRITION OF HEALTHY PULMONARY TISSUE.

I had thought it possible that the mode of nutrition of muscular tissue equally applied to pulmonary tissue; but the result of the inquiry showed that there is a difference between the two processes. The investigation was carried on in the same way as in the case of flesh:

Three samples of pulmonary tissue from three different oxen, submitted to analysis, gave the following results:—

CLASS I.

Composition of Pulmonary Tissue proper or insoluble in water (mature tissue).

	Analysis I.		Analysis II.		Analysis III.		Mean	
	On 200 grms. Tissue	Proportion	On 200 grms. Tissue	Proportion	On 200 grms. Tissue	Proportion	On 200 grms. Tissue	Proportion
Albuminous material	21·442	100	18·204	100	20·04	100	19·895	100
Phosphoric acid .	0·543	2·53	0·432	2·37	0·467	2·33	0·481	2·41
Potash . . .	0·061	0·28	0·043	0·23	0·050	0·25	0·051	0·25

CLASS II.

Composition of Nutritive Material, entirely colloid.

Albumen . .	12·93*	100	13·9	100	12·257	100	13·029	100
Phosphoric acid .	0·327	2·53	0·33	2·38	0·285	2·32	0·314	2·41
Potash . . .	0·037	0·28	0·033	0·24	0·030	0·24	0·033	0·25

CLASS III.

Composition of Effete Material, entirely crystalloid.

Albuminoid material	1·27	100	1·27	100	1·678	100	1·406	100
Phosphoric acid .	0·060	4·72	0·050	3·93	0·063	3·69	0·058	4·11
Potash . . .	0·475	37·40	0·431	33·94	0·447	26·64	0·451	32·66

Proportion of Phosphoric Acid and Potash in Effete Material.

	Analysis I.		Analysis II.		Analysis III.		Mean
	Found	In 100	Found	In 100	Found	In 100	
Phosphoric acid . .	0·060	11·21	0 050	10·40	0·063	12·35	11·32
Potash	0·475	88·79	0·431	89·60	0·447	87·65	88·68

Amount of Water, Fat, Soda, and Chlorine in 200 *grms. of Pulmonary Tissue.*

	Analysis I. Sheep	Analysis II. Sheep	Analysis III. Sheep	Analysis IV. Lamb	Mean
Water .	157·24	157·56	157·84	160·14	158·2
Fat. .	undetermined	3·56	4·10	5·18	4·28

In 200 grms. Ox-lungs.				
	Analysis I.	Analysis II.	Analysis III.	Mean
Soda . . .	0·453	0·657	0·450	0·520
Chlorine . .	0·463	undetermined	0·415	0·439

* There may have been a mere trace of blood in the pulmonary tissue analyzed, but so little that it cannot have interfered practically with the estimation of the albumen, or with the result in other respects.

By referring to the analyses of muscular tissue, it will be seen that there is a marked difference between the composition of flesh and that of pulmonary tissue, the mature tissue of the lungs containing less albumen and much more phosphoric acid than the mature muscular tissue. The effete material of the lungs is very different from that of muscles, the proportion of albuminous material and potash it contains being much smaller, and that of the phosphoric acid is about ten times less.

In order to establish clearly the difference existing between the composition of muscle and lung, I have constructed the following table, which shows the mean results of the analyses in such a way that a mere glance is required to form an idea of the relative composition of these two different tissues.

Mean composition of Muscle and Lung, in 200 *grms.*

	Mature Tissue		Nutritive Material		Effete Material	
	Muscle	Lung	Muscle	Lung	Muscle	Lung
Albuminous mat[1].	28·070	19·895	5·745	13·029	3·70	1·406
Phosphoric acid .	0·251	0·481	0·051	0·314	0·563	0·058
Potash . . .	0·086	0·051	0·017	0·033	0·764	0·451

In Effete Material.				
	Theory		Found in 100	
			Muscle	Lung
Phosphoric acid	43	Pyrophosphate of potash	42·4	11·32
Potash . .	57		57·6	88·68

The most interesting fact brought out in this inquiry refers to the proportion found to exist between the phosphoric acid and potash effete in muscles and pulmonary tissue,—as, while in the former their proportion is precisely that of pyrophosphate of potash, no such result is obtained in the case of the lungs, where the proportions of these substances exhibit no chemical relation.

This circumstance would appear at first sight to clash with my theory that phosphoric acid and potash must be transformed into crystalloid chemical compounds, with a view to their elimination by a physical process of diffusion; but a close consideration of the circumstances bearing on the case will show that the present discrepancy is very satisfactorily accounted for. I explained, in a communication to the *Lancet* for February 2, 1867, how the evolution of carbonic acid from the lungs during respiration was due to the diffusion of the gas from the blood through the moist substance of the pulmonary vesicles, the same theory being given subsequently by Bert (*Leçons sur la Physiologie comparée de la Respiration,* par Paul Bert. 1870). By passing through the substance of the lung-tissue, carbonic acid must combine with whatever free potash and soda it may contain, and consequently transform most of the potash into crystalloid carbonate of potash; the potash is therefore removed as phosphate and carbonate, but mostly as carbonate; while in the case of muscular tissue, the potash is entirely eliminated as phosphate.

Now, does the colloid condition of phosphoric acid and potash found in animal tissues exist in soil, or only in plants? This a very interesting question, open to investigation. One thing is certain—that the liquid excreta of animals and other liquid manures are, as a rule, crystalloids. Plants take up the material they require in quantities which have no relation with equivalent proportions, thereby forming colloids; thus, if soil should contain phosphate of soda and soluble potash salts, plants will take up phosphoric acid and potash in quantities utterly at

variance with their equivalent weights, leaving behind nearly the whole of the soda. But I have also reason to believe that crystalloid mixtures are transformed, to some extent, into colloids in the earth.

ON THE COLLOID CONDITION OF PLANTS.

As a rule, the mineral constituents of plants are very much the same as those of animal tissues; they mostly consist of phosphoric acid, potash, and magnesia; and are very poor in chloride of sodium. Now phosphoric acid and potash are found in a great measure in the colloid state in vegetable as well as in animal tissues. The vegetables I have examined are wheat or wheaten flour, potato, and rice, selecting those mostly used as food for man. It is remarkable that, although the total amount of phosphoric acid and potash they contain varies, still we find, after dialyzing for twenty-four hours a mixture of these materials with water, the same or nearly the same relation to exist between the colloid and total phosphoric acid and the colloid and total potash respectively in each of them. The analysis was conducted in the following way. 100 grammes, say, of wheaten flour were mixed with enough distilled water for the whole to be nearly liquid; and this was placed in a dialyzer which was floated for twenty-four hours over a bulk of water equal to eight or ten times that of the contents of the dialyzer; the volumes of the contents of the dialyzer and of the solution outside were there determined. The material in the dialzyer was next dried and incinerated, and the ash analyzed for the determination of the phosphoric acid and potash. On the other hand, a certain quantity of the flour was carefully incinerated, and the phosphoric acid and potash were determined in the ash. A correction had to be introduced in the analysis by diffusion, owing to the colloid mass still holding a proportion of diffusible phosphoric acid and potash, depending on the relation existing between the volumes of fluid in and out of the dialyzer.

Thus, if the volume of the outside solution was eight times that of the contents of the dialyzer, one eighth of the phosphoric acid found outside the dialyzer would have to be subtracted from the phosphoric acid found in the dialyzer in order to obtain the correct proportion of colloid phosphoric acid. The following table shows the result of these analyses:—

Phosphoric Acid and Potash, total and colloid, in Flour, Potato, and Rice, in 100 *grms.*

Total Phosphoric Acid		Colloid Phosphoric Acid	Total Potash	Colloid Potash
Flour . .	0·3142	0·2062 found	0·1797	0·0557 found
Potato, No. I. .	0·0911	0·0581 ,,	0·5801	0·2175 ,,
Potato, No. II.	0·111	0·0698 ,,	0·678	0·263 ,,
Rice . .	0·2020	0·1144 ,,	0·0856	0·2828 ,,

Proportions.

	Total. Colloid.		Total. Colloid.	
Flour . . .	1 to 0·60	corrected per volume.	1 to 0·21	corrected per volume.
Potato, No. I. . .	1 to 0·58	,,	1 to 0·28	,,
Potato, No. II. . .	1 to 0·54	,,	1 to 0·24	,,
Rice	1 to 0·50	,,	1 to 0·22	,,
Mean . .	1 to 0·55	,,	1 to 0·24	,,

Found means determined in the colloid fluid, the result is calculated for 100 grms. of substance analyzed, and is not corrected per volume. *Corrected per volume* means after deduction of the amount of diffusible phosphoric acid or potash contained in the colloid fluid.

It must be recollected that in an inquiry of this kind it would be next to impossible to obtain figures agreeing perfectly with each other. Indeed physiological processes do not appear to admit of numerical results being always identically the same in all similar cases.

If we inquire into the total amount of phosphoric acid and potash found for the different articles of vegetable food analyzed, we shall observe it, especially that of the potash, to differ so widely in flour, potato, and rice that no resemblance can be traced between these vegetables on

that score. Notwithstanding this fact, the proportion of colloid phosphoric acid and colloid potash to the total phosphoric acid and total potash remains nearly the same in every one of these analyses, the mean proportion being for 100 grammes:—

Phosphoric Acid		Potash	
Total	Colloid	Total	Colloid
1	0·55	1	0·24

This is a very remarkable law of nature, apparently connected with the nutritive properties of the vegetables analysed. It certainly establishes a very interesting relation between the composition of certain vegetable substances destined to the nutrition of animals.

ON THE CONSTITUTION AND NUTRITION OF MUSCULAR TISSUE IN PHTHISIS.

The state of emaciation to which the human body is generally reduced in consumption is a certain indication that in that disease the formation of muscular tissue is deficient; and it occurred to me that the nature of the change the nutrition of flesh undergoes in consumption, and the cause of this phenomenon, might be determined by an inquiry similar to that which had been instituted with regard to the nutrition of muscular tissue in health.

The subject for our present consideration is the nature of the change in the nutrition of muscular tissue which is productive of the emaciation. Now the nutrition of flesh, in consumption, may be either abnormal or merely deficient. If abnormal, the constituents of muscle will be altered in their relative proportions; should it be merely deficient the proportions of their constituents will be the same, but their absolute quantities will be less. We find that the nutrition of muscles in consumptive subjects is abnormal as to the quantity and condition of the water present, amounting to 166·5 instead of 154 for 200 grammes

of flesh in health. On examining the muscular tissue of consumptive individuals, it will usually be observed, especially when there is much emaciation, to be wet and soft, instead of firm and dry, as in the case of death from other diseases. It therefore appears that the water in muscular tissue after death from consumption, besides being in excess, is in a less colloid condition, or, in other words, has not for the other constituents of flesh that peculiar attraction it has in health, and which binds them all together: and it would follow that the soluble colloid constituents of the muscles of consumptive subjects (those substances which become transformed into flesh) are in a less colloid condition than they would be in healthy flesh. If so, this must check more or less the formation of muscular tissue in phthisis. The water being in excess would, of course, account for a deficiency of the solid constituents. The following is a tabular statement of my analyses of human muscular tissue after death from phthisis. Table A. contains the result of an early series of analyses, and does not include any determination of potash.

TABLE A.—*Analyses of Juice of Flesh after death from Consumption.* 200 *grms. of muscle extracted by* 500 *cubic centims. water (calculated for the whole extract, including that retained in the fibres).*

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Mean
Albumen .	6·130	4·265	3·784	4·534	4·332	3·516	4·458	4·156	4·396
Phosphoric acid	—	0·441	0·317	0·441	0·365	0·271	0·354	0·475	0·381
Chlorine . .	0·262	0·341	0·291	0·401	0·466	0·430	0·387	0·390	0·371

TABLE B.—*Constitution and Composition of Human Muscular Tissue after death from Consumption.*

Composition of the Tissue insoluble in water and fibrous.				
	Analysis I. On 200 grms. Tissue	Analysis II. On 200 grms. Tissue	Analysis III. On 200 grms. Tissue	Mean
Albumen, fibrous	20·52	20·52	20·52	20·52
Phosphoric acid	0·160	0·152	0·096	0·103
Potash . .	0·035	0·043	0·026	0·035
Composition of the Nutritive Material, entirely Colloid.				
Albumen . .	4·77	4·437	4·437	4·548
Phosphoric acid	0·037	0·033	0·021	0·030
Potash . .	0·008	0·009	0·006	0·007
Composition of Effete Material, entirely Crystalloid.				
Albuminoid .	2·7	2·7	2·7	2·7
Phosphoric acid	0·318	0·352	0·327	0·332
Potash . .	0·418	0·469	0·439	0·442

Effete Phosphoric Acid and Potash as Pyrophosphate.								
	Analysis I.		Analysis II.		Analysis III.		Mean	Theory
	Found	In 100	Found	In 100	Found	In 100		
Phosphoric acid	0·318	43·2	0·352	42·9	0·327	42·7	42·9	43·0
Potash . .	0·418	56·8	0·469	57·1	0·439	57·3	57·1	57·0

In this Table the result found for the albumen of the fibrous tissue in analysis No. I. was introduced in Analyses II. and III. The albumen of the nutritive material in Analyses II. and III. is the mean of all my determinations of albumen in the extracts.[1]

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[1] The following analysis of human muscular tissue after death from consumption, which was accidentally omitted in my manuscript, confirms strikingly the results obtained in Table B :—

In 200 *grammes.*

	Fibr. proper.	Nutritive.	Effete.
Albuminous	20·52	4·437	2·7
Phosphoric acid	0·176	0·038	0·346
Potash..................	0·075	0·016	0·462

	Found.		Theory. (Pyrophosph. of potash.)
	grm.	per cent.	per cent.
Effete { Phosphoric acid ...	0·346	42·8	43
Effete { Potash	0·462	57·2	57

This is the eighth analysis of flesh which bears out my theory.

These analyses show that, although the solid constituents of flesh be deficient, still they exist in the same relative proportion, or nearly so, as in healthy muscle—the phosphoric acid and potash of the effete material bearing to each other precisely the same relation as they do in pyrophosphate of potash, namely 43 to 57, the exact numbers found being 42·9 to 57·1. It follows that in consumption there is no actual change in the relative proportion of the solid substances concerned in the nutrition of flesh. It is remarkable, however, that the flesh of tubercular subjects should be found to contain more water, chlorine, and soda than muscular tissue does in health.

The proportion of chlorine and soda in healthy muscular tissue and muscle from consumptive subjects is shown in the following table :—

Chlorine and Soda in different samples of Muscular Tissue in Health and after death from Consumption.

In Healthy Muscular Tissue, on 200 grms.			In Muscular Tissue from Consumptive Subjects, on 200 grms.		
Analyses	Chlorine	Soda	Analyses	Chlorine	Soda
I. Ox-flesh	0·196	—	I. . .	0·262	
II. ,,	0·165	—	II. . .	0·341	
III. ,,	0·184	—	III. . .	0·291	
IV. ,,	0·132	—	IV. . .	0·401	
V. ,,	0·173	—	V. . .	0·466	
VI. ,,	0·212	—	VI. . .	0·430	
VII. ,,	undeter.	0·279	VII. . .	0·387	
VIII. ,,	0·210	0·333	VIII. . .	0·390	
IX. ,,	0·094	0·193	—	—	0·385
X. ,,	0·176	0·289	IX. . .	undeter.	0 402
XI. ,,	0·117	0·172	X. . .	0·355	0·434
XII. Human	0·183	0·155			
Mean . .	0·167	0·237[1]	Mean .	0·369	0·437

[1] These chlorine determinations were made by dialyzing for twenty-four hours a known proportion of the watery extract of a given weight of flesh. A portion of the fluid outside the dialyzer was then evaporated to dryness, and the residue was incinerated, the chlorine being determined volumetrically in the solution of the ash. It was finally calculated for the total volume of the

This Table shows that muscular tissue in consumption contains rather more than twice as much chlorine and considerably more soda than it does in health; and from what has been stated above, it follows that muscular tissue in phthisis yields more water, and is moreover wetter than healthy flesh, the proportion of water being 154 for 200 of flesh in health, and 166·5 after death from consumption. Now chlorine and soda do not enter into the composition of the completely assimilated muscular tissue; they form part, however, of the constituents of muscles; and it will be interesting to consider how their increased proportion in the muscles of consumptive patients can be accounted for. The various constituents of flesh, in health, including the water, may be considered as supplied from the blood in the form of molecules, each of them containing certain proportions of these constituents, which may vary in quantity within certain limits. The water, however, is subject to very slight variations, its proportion of 77 per cent. being very tolerably constant. This water binds together in the colloid form the other material which enters into the composition of flesh, so that the constituents of healthy muscle are not wet from the presence of the water, which acts a part not unlike that it would take in the formation of a jelly.

In consumption it appears that the proportion of water in every flesh-molecule the blood yields is too high, and moreover that the constituents of these molecules are not bound together by water as they should be; at the same time the *chloride of sodium* of the blood begins to diffuse into the tissues by a physical process which had been kept in abeyance during the maintenance of health, passing through the capillary vessels into the flesh, just as it would have done through the diaphragm of a dialyzer into water; hence it is that in consumption, the physical force

fluid (in and out of the dialyzer). This may be considered as giving very correct results, twenty-four hours being long enough for chlorine to diffuse out of a dialyzer proportionally to volumes. Chlorides may be safely considered as never being colloid.

of matter is gradually overcoming that force which belongs exclusively to life, the nature of which is still a mystery; and the slow ebb of life in phthisis is a gradual return to a purely physical condition.

ON PULMONARY TISSUE AND ITS NUTRITION IN PHTHISIS.

My inquiries into the chemical changes pulmonary tissue undergoes in phthisis have led to some very interesting results.

In health the lungs consist of a tissue, which from its structure, allows readily of expansion and contraction; this tissue becomes thoroughly permeated with air during respiration, the oxygen of which diffuses through the substance of the lungs and the pulmonary capillary vessels into the blood, the carbonic acid being eliminated from the blood by a similar process. This gaseous diffusion can only take place so long as the soft and delicate walls of the capillary vessels and pulmonary air-vesicles remain physically unaltered; if they should become hardened or changed in any other way, the diffusion of the gases through their substance must be interfered with or entirely checked. Now in the most common form of phthisis, as shown by Dr. Sanderson, the process begins by a new growth of the interstitial tissue of the pulmonary honeycomb, having its seat in the very walls of the blood-vessel. Even at an early stage, the effect of this is not only to diminish the circulation of blood in the affected part, but to render the pulmonary capillaries more and more unfit for the exchange of gases, by diffusion, between the blood and the inspired air. Eventually the air-cells or alveoli in their turn become filled up with a solid material, losing completely their fitness for respiration. Then the tissue softens and breaks down, apparently from the loss of the colloid state of the consolidated pulmonary tissue. It is this last stage which is usually observed after death; and the pulmonary tissue I have submitted to analysis was mostly in that condition. The method of analysis I adopted was precisely the same as that which had been applied to flesh and healthy pulmonary tissue.

Constitution and Composition of Human Pulmonary Tissue (consolidated and softening) in Consumption, in 200 *grms.*

	Analysis I.	Analysis II.	Analysis III.	Mean	Mean On 100 Albumen
Composition of the Tissue insoluble in water.					
Albumen	17·20	14·32	15·63	15·72	100
Phosphoric acid	0·292	0·288	0·286	0·289	1·84
Potash	0·031	0·025	0·026	0·027	0·17
Composition of the material considered nutritive.					
Albumen	7·63	6·98	6·57	7·06	100
Phosphoric acid	0·129	0·140	0·120	0·130	1·84
Potash	0·014	0·012	0·011	0·012	0·17
Composition of the material considered effete, entirely Crystalloid.					
Albuminoid	2·04	2·066	3·059	2·388	100
Phosphoric acid	0·220	0·230	0·377	0·276	11·55
Potash	0·272	0·268	0·365	0·302	12·65
In 200 grammes of Tissue.					
Water	164·00	167·00	164·00	165·00	
Fat	4·17	3·31	4·25	3·91	
Soda	0·582	0·580	0·471	0·544	
Chlorine	0·450	0·470	0·437	0·452	

Effete Phosphoric Acid and Potash.

	Found	In 100	Found	In 100	Found	In 100	Mean In 100	Theory. Pyroph. of Potash In 100
Phosphoric acid	0·220	44·7	0·230	46·8	0·377	50·8	47·7	43
Potash	0·272	55·3	0·268	53·2	0·365	49·2	52·3	57

In analysis No. I. the soft semifluid portions of tissue were separated as much as possible, and the harder portions only submitted to analysis. In the other two analyses no such selection was made.

The principal and most striking results obtained from the analysis of pulmonary tissue, consolidated and softening, are :—

1st. A considerable reduction in the amount of albu-

men, phosphoric acid, and potash, both in the insoluble tissue, and in the nutritive material, compared with the amount of these substances in healthy pulmonary tissue, while the proportion of these substances effete and crystalloid in the diseased tissue is considerably increased. This shows a diminished rate of nutrition, while there is an increase of material to be eliminated, apparently from a deficient action of that process which under normal circumstances causes its removal.

2nd. That the state of semifluidity in which tubercular lungs are usually found after death, is attended with but a trifling increase in the quantity of water beyond the proportion lungs contain in health—water in the normal tissue amounting to 79·1 per cent., and in the diseased to a mean of 82·5 per cent. At first sight this softening appears to be unaccountable; but on a closer consideration the fact admits of an explanation. It may be conceived that in the earlier stage of phthisis the adenoid (tubercular) cells are held together by a colloid attraction, but that after a time, and under certain influences which lower the vital power, this colloid attraction becomes lessened and softening takes place.

3rd. The relative proportions of effete phosphoric acid and potash in the three analyses are very remarkable, as they are found to be quite different from what they are in health. In the normal condition, pulmonary tissue contains effete phosphoric acid and potash in the mean proportion of 11·32 to 88·68, there being a great deal more potash than is necessary for the formation of a pyrophosphate; and I explained how the removal of the potash could be satisfactorily accounted for, by assuming that it was transformed into a carbonate by the carbonic acid set free during the process of respiration. Now as respiration cannot possibly take place in tuberculosis where the pulmonary structure is altered, if my view be correct we shall expect to find in the effete material of tubercular lungs the proportion between the phosphoric acid and potash materially changed; indeed, as these substances must be

removed by a process of physical diffusion, we shall conclude that their relative proportions must be such as to form a crystalloid body. The mean relation obtained was,

Phosphoric Acid . . .	47·7,
Potash	52.3,

which approximates the formation of a pyrophosphate of potash, requiring

Phosphoric Acid . . .	43,
Potash	47.

I have therefore to point out the singular fact that consolidated and softening lungs in phthisis undergo a process of *nutrition* which appears to be allied to that of muscular tissue.

CONCLUSIONS.

The conclusions I have arrived at from the inquiry which forms the subject of the present paper may be summed up as follows:—

1st. That there is a safe ground for the belief that the elementary physical constitution of muscle, and of other animal tissues, is similar to that of a jelly—with this difference, that it is an organized jelly whose fibrinous or cellular form gives it due tenacity for the performance of its functions; but its water, albumen, and other constituents appear to hold the same physical relation to each other as would water to gelatine in jelly.

2nd. That all tissues are formed of three different classes of substances, namely:—those which constitute the ripe tissue, or the portion of the tissue insoluble in water; next those constituting the nutritive material of the tissue, which are soluble in water and colloid; and, finally, those of which the effete material is formed; they are soluble in water, crystalloid, and diffusible.

3rd. That the nutritive material and ripe tissue have the same chemical composition, so that the mature tissue is merely an organized form of the nutritive material, the change being purely morphological.

4th. That in muscular tissue the whole of the phos-

phoric acid is eliminated under the form either of a neutral tribasic phosphate or a pyrophosphate of potash; while at the same time there exist in flesh certain quantities of phosphoric acid and potash which are not in the proportion of a phosphate, and take part exclusively in the actual formation of the mature tissue. This is, I believe, the first time it has been shown with mathematical accuracy by a physiological mode of reasoning, if I may so express it, how substances are brought together and combine in obedience to those laws which regulate and maintain the phenomena of life.

5th. That the albuminous constituents of muscular tissue appear to be eliminated, in the process of waste, under the form of kreatine, kreatinine, and other crystalloid substances.

6th. That blood yields to flesh considerably more potash than is required for the formation of muscular tissue, the excess being necessary for the elimination of the phosphoric acid by converting it into a crystalloid phosphate.

7th. That the nutrition of pulmonary tissue differs from that of muscles, from the parenchyma or substance of the lungs containing a much larger proportion of nutritive material and much less waste, showing apparently that the tissue of the lungs undergoes a more rapid nutrition than that of the muscles.

8th. That while in muscles the phosphoric acid and potash are eliminated in the form of a crystalloid phosphate, in pulmonary tissue there is every reason to believe that the potash is eliminated in a very great measure as a crystalloid carbonate, due to the action of the carbonic acid emitted from the blood during its circulation through the lungs. The effete material in muscles contains phosphoric acid and potash in the proportion of 43 to 57, and in lungs in the proportion of 11·32 to 88·68.

9th. That wheaten flour, potato, and rice contain certain proportions of colloid phosphoric acid and colloid potash, which exist in the three kinds of vegetables very nearly in the ratio of one part of total phosphoric

acid to 0·55 part of colloid phosphoric acid, and one part of total potash to 0·24 part of colloid potash—thus establishing the remarkable fact that, at all events in the three above kinds of vegetable food, although the proportion of phosphoric acid and potash respectively differ, still the proportion of total to colloid phosphoric acid and potash in each of them remains very nearly the same.

10th. That in phthisis a given weight of muscular tissue contains less nutritive material than it does in health, less mature or insoluble tissue, rather more water, and a much higher proportion of chlorine and soda.

11th. That, in phthisis, the phosphoric acid and potash effete in muscular tissue are present exactly in the right proportion for the formation of a pyrophosphate, as occurred in healthy flesh. This shows that the process of waste of muscles in phthisis takes place precisely as it did while in the state of health, and confirms the result relative to the composition of the effete material of muscular tissue, eight analyses of flesh yielding phosphoric acid and potash effete in the proportion of a pyrophosphate.

12th. That the emaciation in phthisis appears due mainly to the blood not being in the proper condition to supply nutritive material to muscular tissue. The damp or wet state peculiar to muscles after death from phthisis appears to show that the colloid state of flesh in that disease is somewhat deficient.

13th. That the tubercular or adenoid formation in pulmonary tissue actually undergoes nutrition, and is consequently *a growth*, the phosphoric acid and potash being apparently eliminated, as in the case of flesh, under the form of a crystalloid phosphate. The nutrition of the abnormal growth accounts for the absence of any smell of decomposition, which is nearly invariably observed at the post-mortem examination when performed shortly after death from consumption.

14th. The process of softening of the tubercular substance appears due to a loss of colloid power; it can hardly be owing to an increase in the proportion of water, as

there is but very little more water in softening tubercular lungs than in healthy lungs—the proportion being, for 200 grammes of tissue, 158 in healthy lungs to 165 in pulmonary tubercular growth, partly softening, partly consolidated.

15th. That there is apparently no increase of fat in tubercular pulmonary tissue, there being a mean of 4·28 of fat in 200 grammes of healthy lungs, and 3·91 in a similar weight of the diseased tissue; but as there is a little more water in the diseased than healthy lungs, it follows that a given weight of tubercular matter from the lungs apparently contains, proportionally to its dry residue, a little more fat than healthy pulmonary tissue under a similar circumstance.

16th. That in nature soluble matter is undergoing a perpetual transformation—passing, in rotation, from the crystalloid into the colloid condition, and from the colloid into the crystalloid condition. Animal secretions and the products of decomposition of animal and vegetable tissues are crystalloid, admitting of their ready distribution through land and water by a physical process of diffusion. These crystalloid substances are transformed into colloids by plants and used in that form as food for animals; and both plants and animals yield them back again in their original crystalloid condition. Chloride of sodium alone appears to be an exception to this rule.

I must express my regret at having retained the old notion rather than adopt the new one now in general use. This has been done because it appeared to me that $2KO.PO_5$, according to the old rotation, expressed more obviously the results of the analysis, in the physiological point of view taken as the basis than the modern expression $K_4P_2O_7$.

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